

Climate Change Learning Progressions

Nancy Butler Songer

Professor of Science Education and Learning Technologies

The University of Michigan

19 April 2012

What are Learning Progressions?

- How are they defined?
- What knowledge do they represent?
- What role(s) do they serve?

Learning Progressions Defined

Learning Progressions take a stance about both the nature and the sequence of core content and science practices that students should develop over multiple curricular units and years.

(National Research Council, 2007; Songer, Kelcey and Gotwals, 2009)

Learning Progressions Defined

Learning Progressions take a stance about both **the nature and the sequence** of core content and science practices that students should **develop over multiple curricular units and years**.

(National Research Council, 2007; Songer, Kelcey and Gotwals, 2009)

What Knowledge Do They Represent?

Learning Progressions take a stance about both the nature and the sequence of **core content** and **science practices** that students should develop over multiple curricular units and years.

(National Research Council, 2007; Songer, Kelcey and Gotwals, 2009)

Classification Content Strand

Last Update 2008.09.12

There are other interactions besides eating, interactions + actors make ecosystems

6th Grade

Organisms interact by eating each other

- C8. Patterns of shared characteristics reveal the evolutionary history of groups (e.g., the shared characteristics of birds and crocodiles supports the relationships of birds to reptiles and their grouping into "Reptilia").
- C7. Classification is important for communication, and it helps us make educated guesses about organisms. If we know enough about an organism to classify it, then we can predict that it will have other characteristics of the organisms in its group, even if we don't observe them directly.
- C6. Classification is hierarchical. (similar species are grouped into one genus, similar genera into one family, similar families into one order, etc.).
- C5. Organisms are grouped based on the structures they have in common. This is called classification.

4th Grade

- C4. Organisms (animals) have different features that they use to survive in different habitats. There are observable internal and external differences (some fly, some have scales, fur, wings, live in the water, etc.). Some of these differences are used to distinguish major groups.
- C3. Plants and animals differ in the types of observable structures they have and what function those structures have.
- C2. Animals and plants are both alive. (Plants and animals grow, breathe, move, reproduce, need energy, have cells.)
- C1. There are observable features of living things (grow, breathe, move, reproduce, need energy, have cells), once living things, and non-living things.

Classification Content Strand

Ecology Content Strand

- E13. Because many animals rely on each other, a change in the number of one species can affect many different members of the web.
- E12. The network, the organisms, their relationships, and the non-living environment in which they live, is called an ecosystem.
- E11. The web of relationships has many links between plants and animals. Most animals need plants for food, sometimes shelter, sometimes water. Plants need decomposers to convert dead organisms into nutrients they need, plants sometimes need animals to help them reproduce or help transport their offspring.
- E10. Some organisms help others survive, this is called mutualism. We can add these relationships to food webs, but now it's not really just a food web any more, it's a web of different kinds of relationships
- E8. Sometimes organisms compete with other organisms for food, or for other things they need to survive or reproduce. Plants may compete for light, water or nutrients; animals may compete for food or shelter.

E6 (repeated). You can connect the plants and animals in a habitat into a web of eating relationships, a food web.

- E7. Only a small fraction of the energy at each level of a food chain is transferred to the next level. Most of the food energy made by plants is not eaten by herbivores and most of the energy in herbivores is not eaten by carnivores. We can diagram this as an energy flow model, with most of the energy in the plants, a smaller amount in herbivores, and an even smaller amount in carnivores.
- E5. You can connect the plants and animals in a habitat into a web of eating relationships, a food web. Because many animals rely on each other, a change in the # of one species (especially the elimination of one species) can affect many different members of the web
- E5. Trophic relationships between organisms can be diagrammed as a food chain, a linking of predators and prey.
- E4. An animal that eats another organism is a predator; the organism that it eats is called its prey. A parasite eats only a part of another organism and doesn't kill it. The organism (plant or animal) that a parasite feeds on is the host.
- E3. Most animals use particular kinds of organisms for food. Some general groups are herbivores, carnivores, omnivores, and decomposers.
- E2. Organisms can be divided into producers (those that make their own food) and consumers (those that use other organisms or their remains as food).
- E1. Every organism needs energy to live and gets it from food.

5th Grade

Ecology Content Strand

Biodiversity Content Strand

- B11. Human activity and other factors affect biodiversity of ecosystems (introduced species, changing habitat qualities, food web disruptions).
- B10. Biodiversity helps to buffer ecosystems against change and to provide other benefits to humans. Biodiversity can be used as a way to measure the "health" of an ecosystem.
- B9. Natural changes in ecosystems (succession, natural disturbance) affect biodiversity and species composition.
- B8. Ecosystems change naturally over time (succession) in response to changes in non-living environment (climate, geological events) and because of changes in the relationships between species present.
- B7. Biodiversity differs in different areas. It is a useful way of characterizing habitats, it tells you something about the quality of the habitat as a whole for a number of different organisms.

Ecosystems change over time, and biodiversity patterns reflect those changes

- B6. There are many different habitats
- B5. An area has high biodiversity if it has both high richness (taxon or species diversity) and high abundance.
- B4. Biodiversity is a measure of the number and variety of different organisms in a particular area (habitat, ecosystem, or biome, so scale dependent). Biodiversity combines abundance and richness.
- B3. Richness and abundance are two different measures of the amount of animal life in a habitat or area. Abundance is the total number of each kind of animal in the habitat, richness is the number of kinds of animals in an area. (You need a classification system to be able to measure the variety of organisms)
- B2 (same as C4). Organisms (animals) have different features that they use to survive in different habitats. There are observable internal and external differences (some fly, some have scales, fur, wings, live in the water, etc.). Some of these differences are used to distinguish major groups.
- B1. A habitat is a place that provides food, water, shelter, and space for living things.

Biodiversity Content Strand

Upper Anchor

2008: Three Year Content Learning Progression in Ecology and Biodiversity

Lower Anchor

Science Practices Emphasized

Students can

- collect data to answer a particular scientific question
- analyze data to identify patterns or relationships
- construct explanations and predictions

Learning Goals Fuse Content + Practices

- **Content** *Ecology 13*: Because many animals rely on each other, a change in the number of one species can affect different members of the web.
- **Science Practice** *Explanations*: Students build a complete scientific explanation consisting of a claim, two pieces of evidence and reasoning
- **Learning goal**: Students construct scientific explanations to address the question, How have recent changes in the Detroit River affected yellow perch populations?

Middle School Learning Progression, Climate Change Biology

Content Highlighted

SSa. Create representations to document how human activity in your community has positive or negative affects on climate change.

5c. Construct a representation of an explanation to address the scientific question: What does Future 1 look like for my species?

5b. Construct a justified prediction using data to address the scientific question, does Future 1 predict affects on predator-prey interactions for my focal species?

5a. Use a representation of a prediction to analyze the future impact of climate change on the Pike and on a focal species' distribution.

4d. Construct an explanation (using climate data) to address the scientific question, is there scientific evidence to show that human activities have an effect on climate?

4c. Use a video representation as evidence to justify their answer to the question, does human activity have an effect on the climate?

4b. Construct several justified predictions of how human activities influence the rate of future carbon dioxide production and temperature increases using knowledge of the carbon cycle and human activities.

4a. Use a representation (Carbon Card Game) to tell a story about human activities and their associated carbon production.

3c. Construct an explanation to address the scientific question, is there a relationship between carbon dioxide and changing climate?

3b. Create a representation to describe the greenhouse effect.

3a. Create a representation (Carbon Cycle) of the movement of Greenhouse gases through the environmental system.

2d. Construct an explanation to address the scientific question, is there a difference between weather and climate?

2c. Analyze data to identify patterns of average temperature rates over the last 100 years?

2b. Apply mathematical routines (averages) to historic and current temperatures and create representations to compare historic and current average temperatures (climate).

2a. Analyze data of species distribution and abiotic conditions (temperature and precipitation), to identify patterns in abiotic conditions that influence where a focal species lives.

1e. Construct an explanation to address the scientific question, why doesn't my focal species distribution completely overlap with the distribution of its prey?

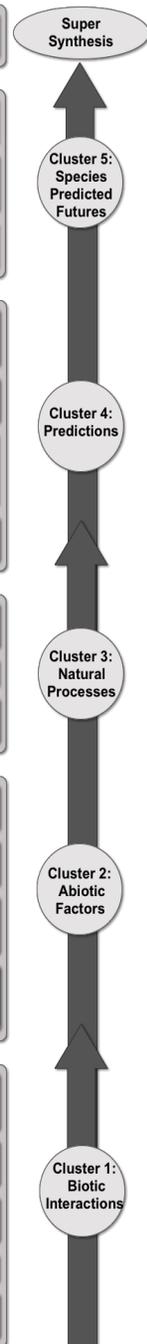
1d. Analyze data in the form of two species distributions to compare the locations of predator-prey habitats.

1c. Use representations in the form of a food web to address the question, what does my species eat and what eats my species?

1b. Analyze data to show where a focal species lives.

1a. Collect data to show how things in the school yard serve as a species' habitat.

Abiotic Biotic Fusion: Abiotic + Biotic



SSa. Create representations to document how human activity in your community has positive or negative affects on climate change.

5c. Construct a representation of an explanation to address the scientific question: What does Future 1 look like for my species?

5b. Construct a justified prediction using data to address the scientific question, does Future 1 predict affects on predator-prey interactions for my focal species?

5a. Use a representation of a prediction to analyze the future impact of climate change on the Pike and on a focal species' distribution.

4d. Construct an explanation (using climate data) to address the scientific question, is there scientific evidence to show that human activities have an effect on climate?

4c. Use a video representation as evidence to justify their answer to the question, does human activity have an effect on the climate?

4b. Construct several justified predictions of how human activities influence the rate of future carbon dioxide production and temperature increases using knowledge of the carbon cycle and human activities.

4a. Use a representation (Carbon Card Game) to tell a story about human activities and their associated carbon production.

3c. Construct an explanation to address the scientific question, is there a relationship between carbon dioxide and changing climate?

3b. Create a representation to describe the greenhouse effect.

3a. Create a representation (Carbon Cycle) of the movement of Greenhouse gases through the environmental system.

2d. Construct an explanation to address the scientific question, is there a difference between weather and climate?

2c. Analyze data to identify patterns of average temperature rates over the last 100 years?

2b. Apply mathematical routines (averages) to historic and current temperatures and create representations to compare historic and current average temperatures (climate).

2a. Analyze data of species distribution and abiotic conditions (temperature and precipitation), to identify patterns in abiotic conditions that influence where a focal species lives.

1e. Construct an explanation to address the scientific question, why doesn't my focal species distribution completely overlap with the distribution of its prey?

1d. Analyze data in the form of two species distributions to compare the locations of predator-prey habitats.

1c. Use representations in the form of a food web to address the question, what does my species eat and what eats my species?

1b. Analyze data to show where a focal species lives.

1a. Collect data to show how things in the school yard serve as a species' habitat.

Scientific Explanations Data Analysis Data Collection

Practices Highlighted

Learning Goals Highlighted by Content

3c. Construct an explanation to address the scientific question, is there a relationship between carbon dioxide and changing climate?

3b. Create a representation to describe the greenhouse effect.

3a. Create a representation (Carbon Cycle) of the movement of Greenhouse gases through the environmental system.

Abiotic

Biotic

**Fusion:
Abiotic + Biotic**

Learning Goals Highlighted by Science Practices

3c. Construct an explanation to address the scientific question, is there a relationship between carbon dioxide and changing climate?

3b. Create a representation to describe the greenhouse effect.

3a. Create a representation (Carbon Cycle) of the movement of Greenhouse gases through the environmental system.

**Scientific
Explanations**

Data Analysis

Data Collection

Cluster 1: Biotic Interactions

1e. Construct an explanation to address the scientific question, why doesn't my focal species distribution completely overlap with the distribution of its prey?

1d. Analyze data in the form of two species distributions to compare the locations of predator-prey habitats.

1c. Use representations in the form of a food web to address the question, what does my species eat and what eats my species?

1b. Analyze data to show where a focal species lives.

1a. Collect data to show how things in the school yard serve as a species' habitat.

Scientific Explanations

Data Analysis

Data Collection

Cluster 2: Abiotic Factors

2d. Construct an explanation to address the scientific question, is there a difference between weather and climate?

2c. Analyze data to identify patterns of average temperature rates over the last 100 years?

2b. Apply mathematical routines (averages) to historic and current temperatures and create representations to compare historic and current average temperatures (climate).

2a. Analyze data of species distribution and abiotic conditions (temperature and precipitation), to identify patterns in abiotic conditions that influence where a focal species lives.

Scientific Explanations

Data Analysis

Data Collection

Cluster 3: Natural Processes

3c. Construct an explanation to address the scientific question, is there a relationship between carbon dioxide and changing climate?

3b. Create a representation to describe the greenhouse effect.

3a. Create a representation (Carbon Cycle) of the movement of Greenhouse gases through the environmental system.

**Scientific
Explanations**

Data Analysis

Data Collection

Learning Progressions

What Roles do they Serve?

Learning Progressions are successively more sophisticated ways of thinking about a topic that **can be used as templates for the development of curricular and assessment products** (Songer, Kelcey and Gotwals, 2009).

Cluster 5: Species Predicted Futures

5c. Construct an explanation to address the scientific question, What does Future 1 look like for my focal species?

5b. Construct a justified predictions using data to address the scientific question, does Future 1 predict effects on predator-prey interactions for my focal species?

5a. Use a representation of a prediction to analyze the future impact of climate change on the Pike and on a focal species distribution.

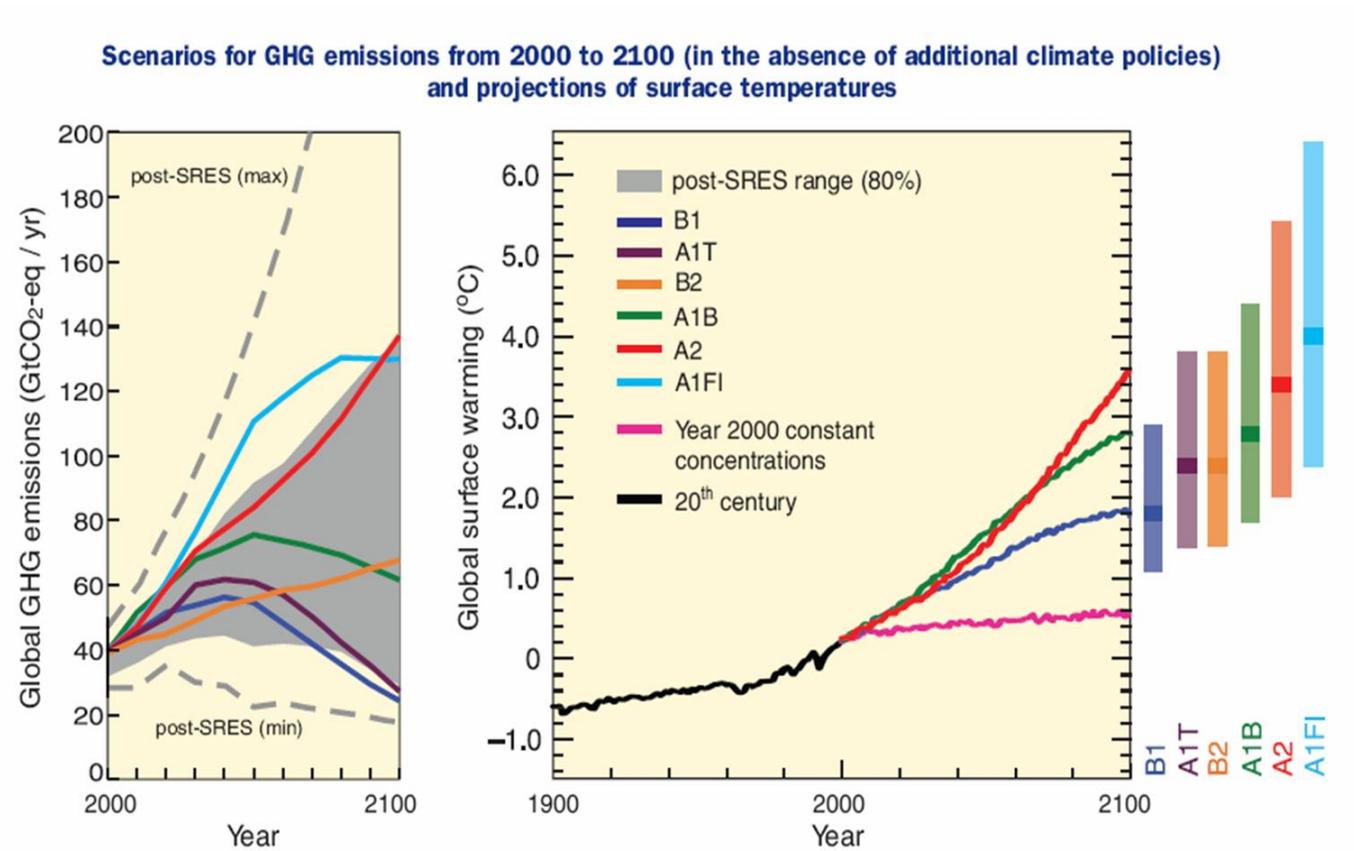
Scientific Explanations

Data Analysis

Data Collection

Scenarios: Alternative futures (IPCC) = COMPLEX

Future **climate change** depends on future greenhouse gas emissions
Future **greenhouse gas emissions** depend on socio-economic choices



Strategic Simplification of Scenarios for Middle Schoolers

Future **climate change** depends on future greenhouse gas emissions
Future **greenhouse gas emissions** depend on socio-economic choices

Population
growth rate



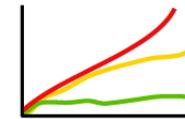
Energy use
per person



Proportion
clean energy



Total CO₂ emissions
by 2100 (gigatons)



Future 1

Fast

Low

Low

1862

Future 2

Slow

High

High

1499

Future 3

Slow

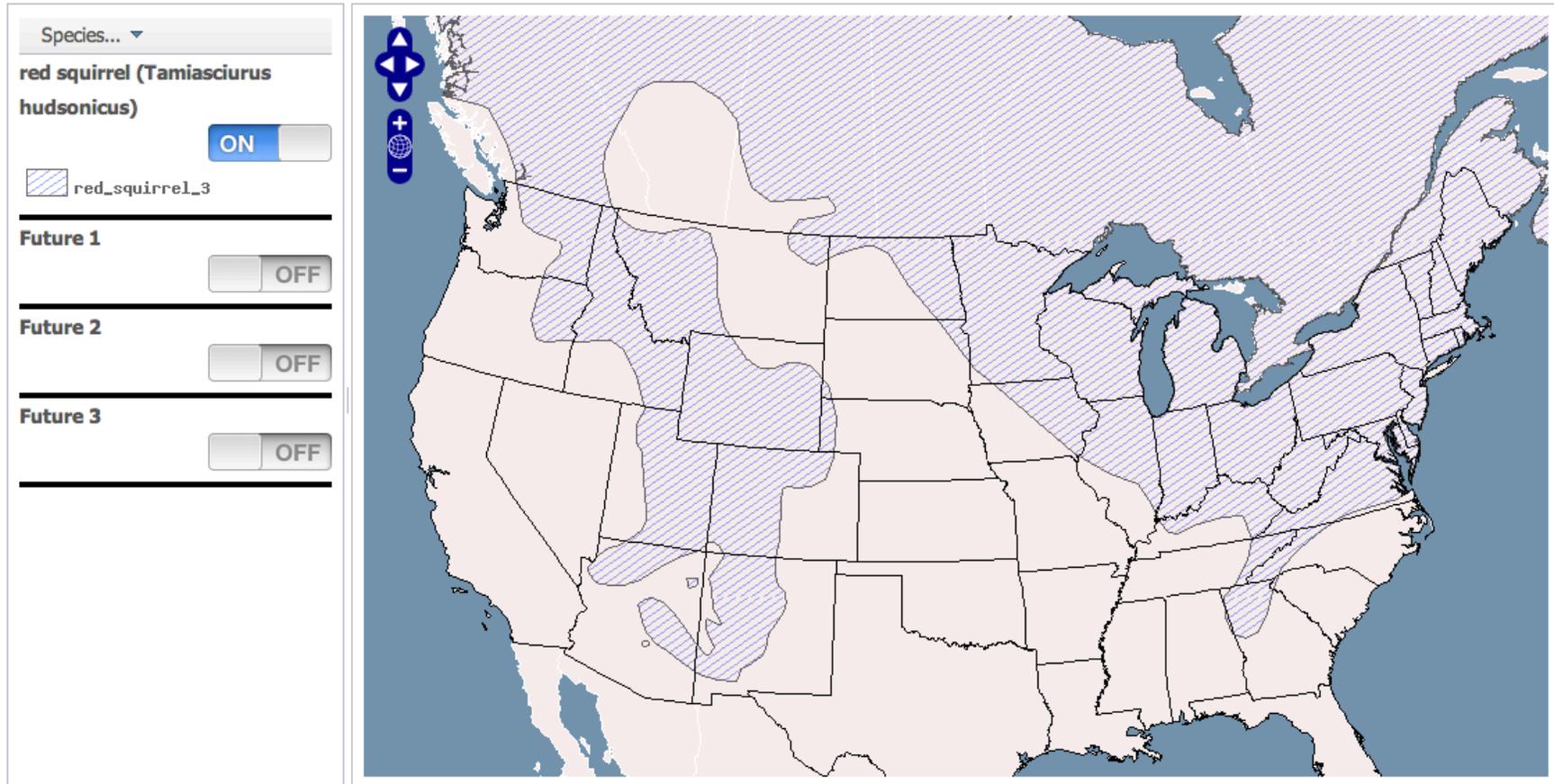
Low

High

983

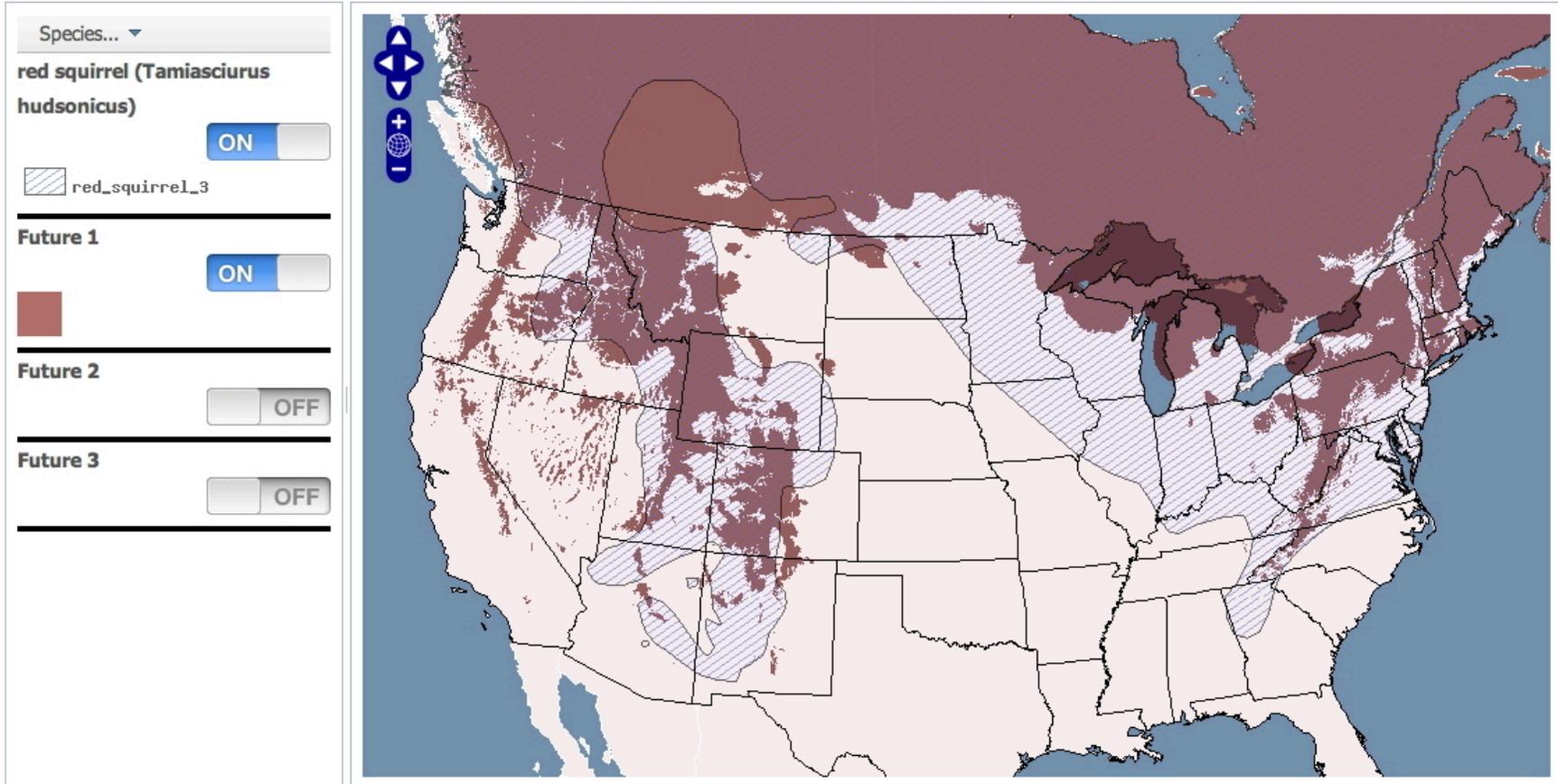
Red Squirrel: Current Distribution

Focal Species Current and Future Distributions



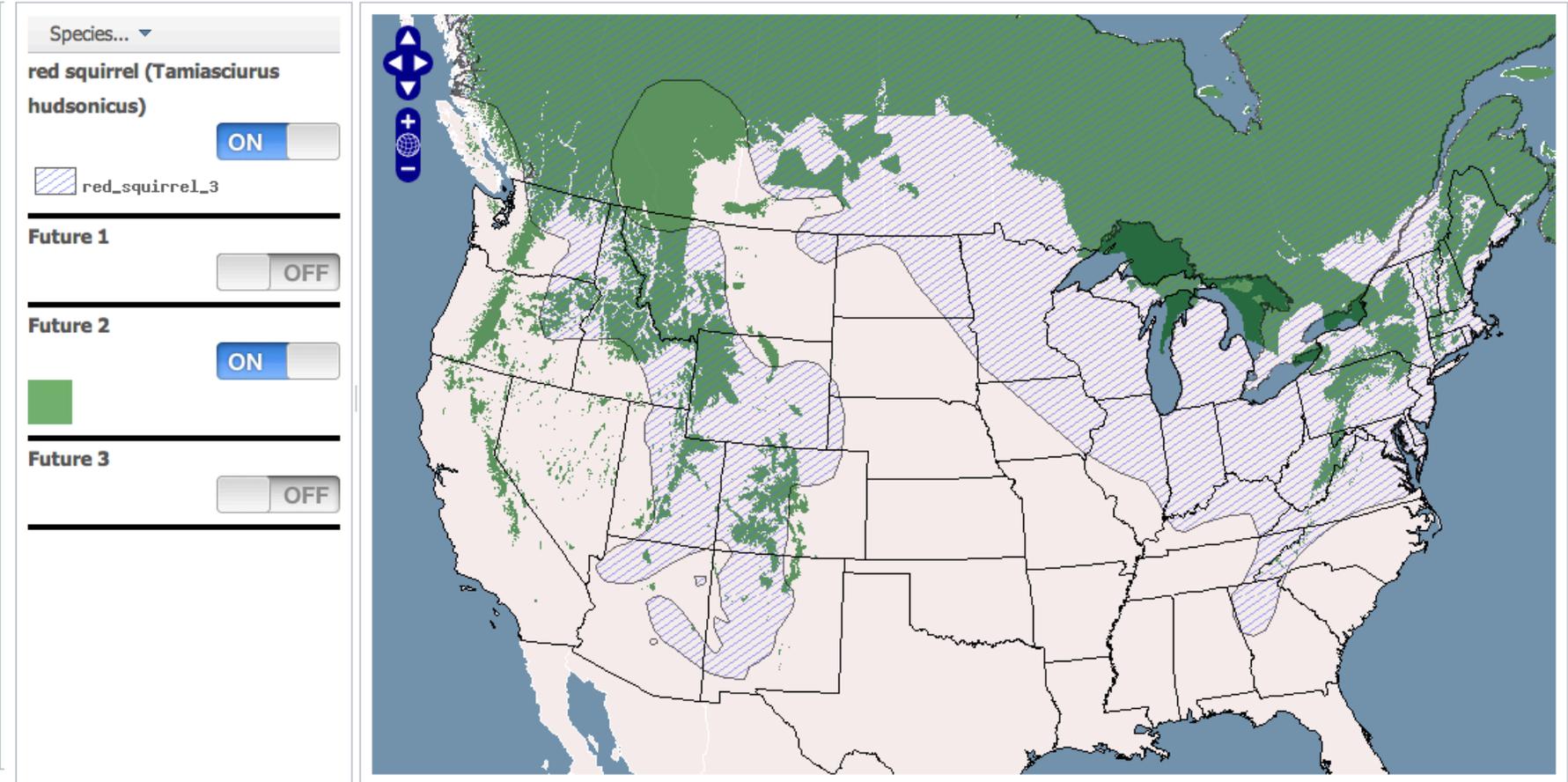
Red Squirrel: Future 1

Focal Species Current and Future Distributions



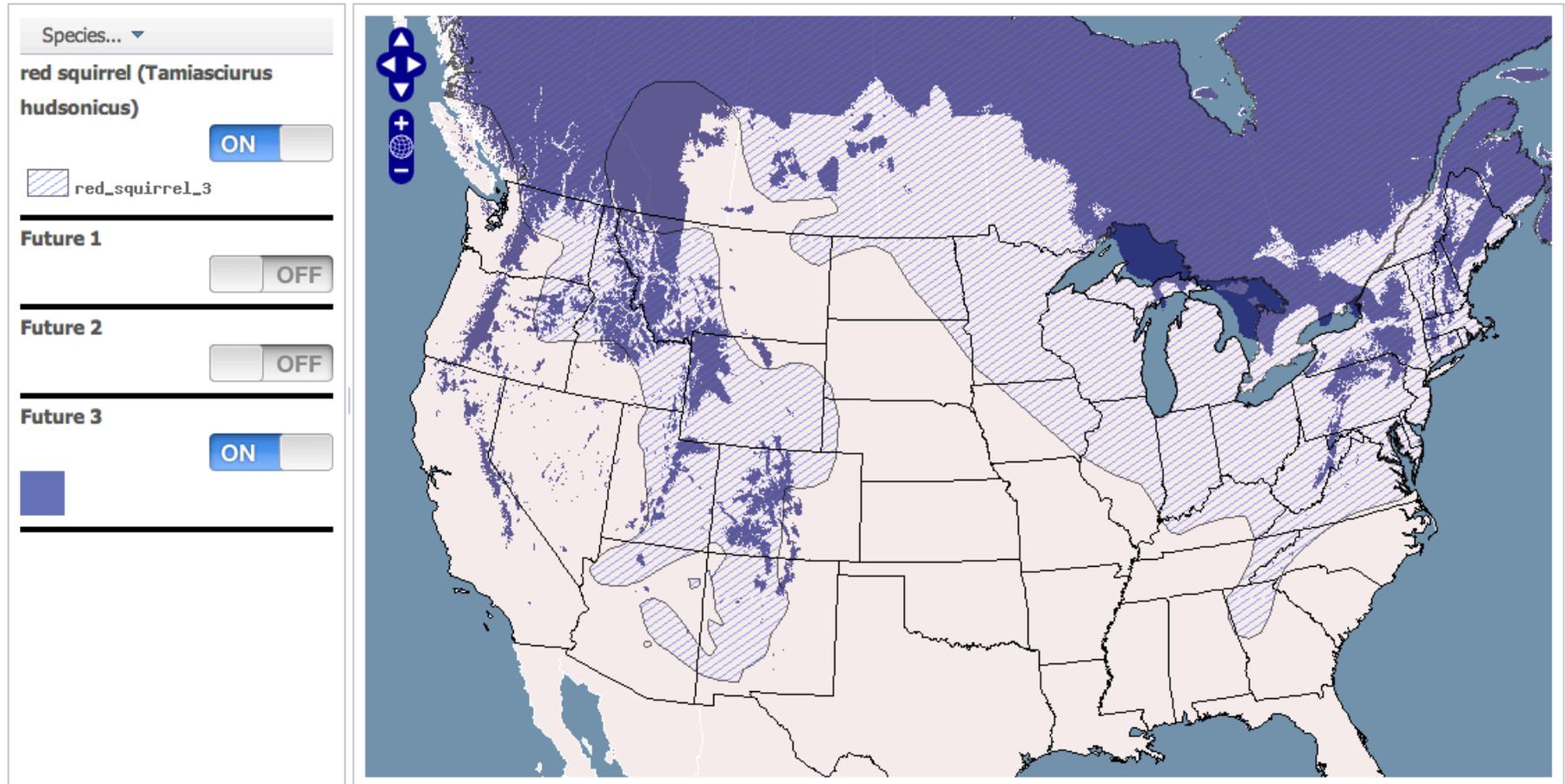
Red Squirrel: Future 2

Focal Species Current and Future Distributions



Red Squirrel: Future 3

Focal Species Current and Future Distributions



Is there evidence that climate change will impact the distribution of species?

The screenshot shows a web browser window with the URL `animaldiversity.ummz.umich.edu/changethinking/species/workbook/65/`. The page features a header with a deer and the word "SPECIES" in large green letters. The main content area is titled "Scientific Question: Is there evidence that climate change will impact the distribution of species?". Below this is a "My Scientific Explanation" section with three input fields: "My claim is:", "My reasoning is:", and "Evidence". Each field has a "Hint" button and a "Science scaffold" box. The "My claim is:" field has a hint: "A claim is your best answer to the question. Claims are go up, down, or stay the same?" and a scaffold box labeled "Science practice scaffold". The "My reasoning is:" field has a hint: "A statement that describes how particular evidence supports a scientific claim. For example, you can use scientific definitions, scientific concepts or ideas to explain why you choose the evidence you did." and a scaffold box labeled "Science content scaffold". The "Evidence" field has a hint: "Evidence are observations, data, or information that helps you answer the scientific question." and a scaffold box labeled "Science content scaffold". To the right of the explanation section is a "Resources" box with links: "Predicted Distribution Modeling", "Predicted Temperature Associated with Future Scenarios", and "Cancel Save" buttons.

Conclusions

- Climate science is a complex, interdisciplinary science; Learning Progressions can **serve as currency** to help us prioritize and share knowledge
- Learning Progressions are essential **templates for the systematic design and evaluation** of higher order, NGSS learning goals (content + practices)
- Creation of LPs requires **deep collaboration** among educator-scientist teams

For More Information

- <http://sitemaker.umich.edu/essentialscience/home> or
- songer@umich.edu, vlpeters@umich.edu